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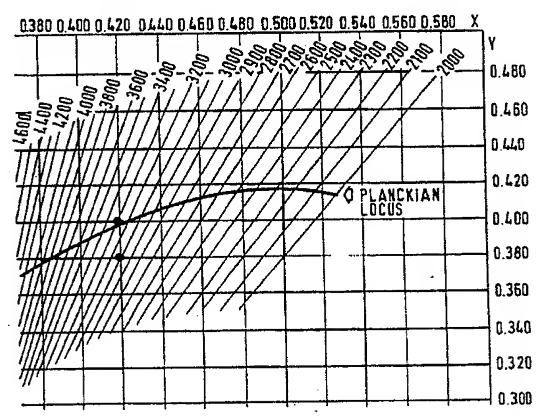
(54) Discharge lamp arc tubes.

(57) A discharge lamp arc tube (1) disposed within an outer envelope (11) of a discharge lamp has a chemical fill comprising an inert starting gas, mercury, sodium iodide, lithium iodide and scandium iodide, and is characterised in that the chemical fill also includes thallium, preferably introduced as an amalgam with the mercury, in an amount whereby the colour coordinates (x,y) lie substantially on the black body curve of a CIE standard chromaticity diagram.

FIG.2

CORRELATED COLOUR TEMPERATURE-ISOTEMPERATURE LINE DIAGRAM



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This invention relates to discharge lamp arc tubes, and more particularly to arc tubes containing sodium, lithium and scandium halides.

Known metal halide lamps typically have a high efficacy of 70 to 110 Lm/W and a CRI of 60 to about 95 depending on metal halide additives and lamp configurations. There are more than fifty different metal halides which may be used alone or in combination in metal halide lamps, and one lamp which has become widely used in the United States due to its very high efficacy (typically 80-110 LM/W and CRI of about 65) is the sodium scandium lamp. However, despite the commercial success of some metal halide lamps, there is a need to further increase the efficacy, colour rendering and operating life of these lamps.

U.S. patent 5,057,743 to Krasko et al describes a low wattage metal halide lamp, which contains a chemical fill comprising mercury, scandium metal, sodium iodide, scandium iodide, lithium iodide, and a starting gas. In the low wattage lamp illustrated, additions of 2-4 mg/cm^3 of lithium iodide included in the chemical fill were stated to increase the CRI from 65 to more than 70, with little change in colour temperature and efficacy. However, it is now recognised that such a lamp with lithium iodide has an undesirable purplish tint of radiation colour which is reflected in a shift of colour coordinates from the black body curve with x=0.420, y=0.395 down to x=0.420, y=0.380.

U.S. patent 4,866,342 to Ramaiah describes a metal halide lamp having a discharge sustaining fill within an arc tube consisting essentially of a rare gas, mercury, and the halides of sodium and scandium, and additionally containing thallium halide in the mole ratio of sodium halide to thallium halide of about 280:1 to 75:1 whereby to increase the luminous efficacy of the lamp. As set forth in column 2, lines 25 to 29, some improvement in both the luminous efficacy and the colour rendering index occurs within the narrow range of 260:1 to 240:1 mole ratio of sodium halide to thallium halide. However, no substantial improvement in CRI is provided over a wide range of molar ratios.

Because of their superior efficacy and operating life, lamps utilizing a chemical fill of $NaIScI_3LiI$ with a scandium metal getter are highly desirable. However, due to their colour rendering properties, their commercial use in certain colour-critical applications has been limited. Hence, further desirable improvements to their colour rendering index is desirable.

Certain terms as used in this specification have meanings which are generally accepted in the lighting industry. These terms are described in the IES LIGHTING HANDBOOK, Reference Volume, 1984, Illuminating Engineering Society of North America. The colour rendering index of a light source (CRI) is a measure of the degree of colour shift objects undergo when illuminated by the light source as compared with the colour of those same objects when illuminated by a reference source of comparable colour temperature. The CRI rating consists of a General Index, R_a, based on a set of eight test-colour samples that have been found adequate to cover the colour gamut. The colour appearance of a lamp is described by its chromaticity coordinates which can be calculated from spectral power distribution according to standard methods. See CIE, Method of measuring and specifying colour rendering properties of light sources (2nd ed.), Publ. CIE No. 13.2 (TC-3,2), Bureau Central de la CIE, Paris, 1974. The CIE standard chromaticity diagram includes the colour points of black body radiators at various temperatures. The locus of blackbody chromaticities on the x,y-diagram is known as the Planckian locus. Any emitting source represented by a point on this locus may be specified by a colour temperature. A point near but not on this Planckian locus has a correlated colour temperature (CCT) because lines can be drawn from such points to intersect the Planckian locus at this colour temperature such that all points look to the average human eye as having nearly the same colour. Luminous efficacy of a source of light is the quotient of the total luminous flux emitted by the total lamp power input as expressed in lumens per watt (Lm/W).

Viewed from one aspect the present invention provides a discharge lamp arc tube having a chemical fill comprising an inert starting gas, mercury, sodium iodide, lithium iodide and scandium iodide, characterised in that the fill further includes thallium in an amount whereby the colour coordinates (x,y) of said arc tube lie substantially on the black body curve of a standard chromaticity diagram.

It has been found that a chemical fill containing both lithium iodide and thallium in suitable amounts can avoid an undesirable purplish tint which would otherwise arise in the absence of the thallium.

Preferably the thallium concentrations are such as to result in colour coordinates x=0.42, y=0.40 located substantially on the black body locus of a CIE standard chromaticity diagram, and preferably the colour temperature is a warm colour temperature of about 3200 K.

An embodiment of the invention will now be described by way of example only, with references to the accompanying drawings, wherein:-

FIGURE 1 is a cross-sectional view of a discharge lamp arc tube disposed within a metal halide discharge lamp;

FIGURE 2 is an x-y chromaticity diagram according to the 1931 standard showing the Planckian locus and the colour correction made in accordance with an embodiment of the present invention.

FIGURE 3 is a graph showing CRI on one y-axis, Lm/W on another y-axis with thallium concentration in mg/cm^3 on the x-axis.

Referring to FIGURE 1, there is shown the structural features of a metal halide lamp discharge lamp.

The illustrated lamp includes a quartz discharge tube or arc tube 1 disposed within an outer sealed glass envelope 11. The outer envelope is most preferably evacuated. The outer envelope 11 is hermetically sealed to an affixed glass stem member 14 having an external base member 10. A pair of electrical conductors 18 and 19 are sealed into and pass through the stem member 14.

The discharge tube 1 has a pair of electrodes 2 and 3 which project into the interior of the discharge tube 1 at respective ends and provide for energizing of the discharge lamp by an external source (not shown) during operation. Discharge tube 1 is generally made of quartz although other types of material may be used such as alumina, yttria or silica. Each electrode 2 and 3 comprises a core portion surrounded by molybdenum or tungsten wire helixes.

Each of the electrodes 2 and 3 is connected to respective metal foils 4 and 5, preferably formed of molybdenum which are pinch sealed. Electrical conductors 6 and 7 which are electrically connected to respective foils, 4 and 5, extend outwardly of the respective press seals. Conductors 6 and 7 are respectively connected to the conductors 18 and 19 projecting from the glass stem member 14. As illustrated in the drawing, the connection between conductor 6 and conductor 18 is made by a vertically disposed wire extending exterior to a radiation shield 13. A pair of getters 20 and 21 are mounted to a support structure 12.

Within the outer envelope 11, the support member 12 which is secured to the glass stem member 14 and extends substantially parallel to the longitudinal axis of the lamp includes an envelope attachment 15 at one end. The envelope attachment 15 is in the form of a circular configuration which mates with a dimpled upper portion of the envelope 11 so as to maintain the support structure 12 in proper alignment and resist deformation caused by external shock.

The radiation shield 13 is secured to the support structure 12 by spaced apart straps 16 and 17 which are respectively welded to a vertically aligned portion of the support member 12. The radiation shield 13 has a cylindrical shape and is typically in the form of a quartz sleeve which can have a domed shaped closure at one end. Each of the straps 16 and 17 is made of a spring like material so as to grippingly hold the shield 13 in position. The diameter and length of the radiation shield may be chosen with respect to the arc tube dimensions to achieve the optimal radiation redistribution resulting in uniform arc tube wall temperatures.

It will be seen that the discharge tube 1 which is positioned interior the radiation shield 13 is electrically isolated from the radiation shield 13 and the support structure 12. Such a "floating frame" structure is used to control the loss of alkali metal from the arc tube fill by electrically isolating the support structure. Thus, the conductors 6,7,18 and 19 do not come into contact with the radiation shield 13 or the support structure 12 to which it is connected by straps 16,17, and furthermore the stem member 14 is of low electrical conductivity so as to isolate the conductors 18,19 from the support 12 secured to the stem by means of a strap.

The drawing illustrates a mogul type base, e.g., such as an E27 screw base but it is contemplated that the lamp may have a double-ended configuration with a recessed single-contact base. The discharge tube for use in a 100 watt size lamp, for example, has an internal diameter of 10 mm and an arc length of 14 mm.

The lamp may include other structural features commonly found in metal halide lamps such as an auxiliary starting probe or electrode, generally made of tantalum or tungsten which may be provided at the base end of the arc tube adjacent the main electrode 3.

The discharge tube 1 contains a chemical fill of inert starting gas, alkali metal iodides, and scandium iodide and an amalgam containing mercury which is at least partially vaporized during lamp operation and which are dispensed into the unsealed arc tube prior to introduction of the starting gas.

A charge of mercury is present in a sufficient amount so when fully vaporized an arc may be sustained. Such an amount should provide an operating mercury-vapor pressure of from 1 to 10 atmospheres as calculated on the basis of an average gas temperature of about 2000°K. More preferably the mercury dosage in the chemical fill of a lamp may be calculated in accordance with the formula:

$$N(Hg)\ (mg/cm^3) = 7.7\ D^{1/7}$$

wherein D is the arc tube diameter in millimetres.

In accordance with the present invention, the chemical fill also comprises thallium. The thallium could be introduced into the arc tube as thallium iodide, but is more preferably introduced as thallium metal. Preferably thallium is introduced into the arc tube in the form of an amalgam comprising mercury and thallium metal. The improved chemical fill of the present invention comprising the base $NaI\text{-}ScI_3\text{-}Li$ chemistry with thallium for enhancing the lamp colour, bringing the colour coordinates to the black body locus.

Thallium metal present in the arc tube in the form of the amalgam combines with elemental iodine which is always present in the arc tube to form thallium iodide. Thallium iodide has three orders of magnitude higher saturated vapor pressure than thallium metal at the lamp operating temperatures. The amount of thallium present in the amalgam is sufficient so that the amount of thallium iodide formed is sufficient for making only the desired colour correction to the emitted light. Preferably the amount of thallium metal present in the initially introduced amalgam

is from about 0.01 to 0.2 mg/cm^3 of the arc tube volume.

In addition to mercury, a small charge of an inert ionizable starting gas such as argon is contained within the discharge tube 1. It is contemplated that other noble gases can be substituted for argon provided an appropriate pressure is maintained that is conducive to starting the lamp.

The fill mixture containing scandium halide and alkali metal halides is desirable for achieving a high lumen output. The preferred ingredients scandium iodide and the alkali metal iodides are preferably present in a ratio which provides a warm colour of lamp light output match up or comparability to the output of an incandescent lamp. Preferably sodium iodide and scandium iodide are present in a molar ratio of from amount 20:1 to about 28:1. It has been found in comparison of various molar ratios of sodium and scandium iodides in sodium-scandium lamps similar to that shown in Fig. 1, that ratios within this range most closely approach the black body curve, have a desirable colour temperature and efficiency, and maintain a relatively high CRI within this range.

In further tests on lamps similar to that shown in Fig. 1, the amount of lithium iodide included in the chemical fill of a lamp otherwise including mercury, scandium metal, sodium iodide and lithium iodide was varied and the luminous efficacy, operating voltage, colour temperature and CRI were monitored. It was found that desirable characteristics were achieved with certain molar ratios of alkali metal iodides (lithium iodide + sodium iodide) to scandium iodide. The amounts of alkali metal iodides to scandium iodide is preferably in a molar ratio of about 27:1 to about 40:1. A preferred ratio of sodium iodide to lithium iodide is a molar ratio of from about 1:1 to about 5:1.

Preferably the amount of lithium iodide in the chemical fill of the lamp is about 2-4 mg/cm^3, more preferably about 3 mg/cm^3, wherein the molar ratio of alkali metal iodides to scandium iodide is maintained within the range of about 27:1 to 40:1.5. This amount of LiI has been found to significantly increase the lamp CRI without detrimentally affecting luminous efficacy or colour temperature (See U.S. patent 5,057,743). In the absence of thallium lamps of this type typically have a purplish tint since the colour coordinates are located below the black body locus with x=0.420 and y=0.380.

In addition to the above-mentioned components, scandium metal, thorium metal, and mixtures thereof may be added to the fill. A weight dose of scandium elemental metal in the fill has been found desirable to adjust the metal/iodine ratio in the lamp and to getter oxygen impurities.

When the base chemistry of the lamp, excludes thallium, i.e. the constituents comprises the NaI-ScI_3-LiI_3 fill ingredients, the colour of the lamp is displaced from the black body locus as shown in FIG 2. FIG 2 shows that the addition of a sufficient amount of thallium brings the lamp colour coordinates to the black body locus. The data was obtained using a 100 watt lamp having a configuration similar to that shown in FIG. 1 with a quartz arc tube having ID-10 mm and an arc gap of 14 mm. The amount of thallium was varied from 0 to 0.15 mg. The fill otherwise comprised 12 mg mercury, 0.13 mg scandium metal, 6.8 mg sodium iodide, 0.8 mg scandium iodide, 2.4 mg lithium iodide and 13000 Pa (100 torr) of argon for starting.

The curves of FIG. 3 show that the lamp luminous efficacy and CRI increased with increasing amounts of metal thallium in the amalgam. The preferred amount of thallium is from 0.05 to 0.07 mg/cm^3 for providing high lamp efficacy of about 95 Lm/W, high CRI of about 80, a warm colour temperature of 3200K, and colour coordinates x=0.42, y=0.40 located on the black body locus. Thallium concentrations greater than 0.1 mg/cm^3 may undesirably provide too much green colour emission resulting in an undesirable shifting of y-coordinates above the black body locus.

Preferred embodiment of the present invention advantageously utilize thallium metal instead of thallium iodide in the lamp chemical fill. Thallium metal readily alloys with the mercury and does not separate within the range of 0 to 10 percent thallium. A thallium/mercury amalgam has the same viscosity as pure mercury and does not stick to the glass walls during lamp dosing. Since the amalgam is not hygroscopic, unlike most of the iodides, a thallium containing amalgam is more forgiving than using thallium iodide in lamp production.

Preferably, the present invention may advantageously be used for low wattage type metal halide discharge lamps, i.e., those lamps with a wattage less than 175 watts, for example 35 to 150 watts. Preferred lamps have a volume of 0.3 - 2.2 cm^3, with a chemical fill consisting essentially of about 10 to 13 mg/cm^3 mercury and about 12000 Pa to about 20000 Pa (about 90 to about 150 torr) starting gas; about 0.5 to about 4.5 mg/cm^3 scandium iodide; about 5 to about 25 mg/cm^3 sodium iodide; and about 2 to 4 mg/cm^3 lithium iodide. The amount of thallium is preferably from about 0.05 to about 0.07 mg/cm^3. Preferably the tube has a wall loading in the range of about 14 to 17 watts/cm^2.

Thus, in at least preferred embodiments there is provided an improvement in the quality of white light emission from a high intensity discharge lamp utilizing the NaI-ScI_3 and LiI chemistry while maintaining the efficiency and long life characteristic of such a lamp; and there is provided a lamp in which the lamp colour coordinates are brought back to the black body curve in order to eliminate an undesirable purplish tint of the lamp colour which would otherwise occur in the absence of thallium without sacrificing lamp performance; and there is provided a method of accurately and reproducibly introducing the chemical fill in the

arc tube in order to provide good lamp to lamp colour uniformity and colour stability through lamp life.

While there has been shown and described what at present is considered a preferred embodiment of this invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the invention.

Claims

1. A discharge lamp arc tube having a chemical fill comprising an inert starting gas, mercury, sodium iodide, lithium iodide and scandium iodide, characterised in that the fill further includes thallium in an amount whereby the colour coordinates (x,y) of said arc tube lie substantially on the black body curve of a standard chromaticity diagram.

2. A discharge lamp arc tube as claimed in claim 1, characterised in that said colour coordinates (x,y) which lie substantially on the black body curve are x=0.42, y=0.40.

3. A discharge lamp arc tube as claimed in claim 1 or 2, characterised in that said discharge lamp arc tube has a colour temperature of about 3200 K.

4. A discharge lamp arc tube as claimed in any preceding claim, characterised in that said chemical fill includes thallium and mercury as an amalgam.

5. A discharge lamp arc tube as claimed in any preceding claim, characterised in that said thallium is present in an amount from about 0.05 to about 0.07 mg/cm^3 of arc tube volume.

6. A discharge lamp arc tube as claimed in any preceding claim, characterised in that said chemical fill includes sodium iodide and lithium iodide in a molar ratio of from about 1:1 to about 5:1.

7. A discharge lamp arc tube as claimed in any preceding claim, characterised in that said chemical fill further includes a metal or metal alloy selected from the group consisting of scandium metal, thorium metal, and mixtures thereof.

8. A discharge lamp arc tube as claimed in any preceding claim, characterised by a luminous efficacy of about 95 Lumens/Watt.

9. A discharge lamp arc tube as claimed in any preceding claim, characterised by a CRI of about 80.

10. A discharge lamp arc tube as claimed in any preceding claim, characterised in that said arc tube has a wattage of between about 35 to 150 watts.

11. A discharge lamp arc tube having a chemical fill comprising an inert starting gas, mercury, one or more alkali metal halides including at least a lithium halide, and a scandium halide, characterised in that the fill further includes thallium in an amount whereby the colour coordinates (x,y) of said arc tube lie substantially on the black body curve of a standard chromaticity diagram.

FIG. 1

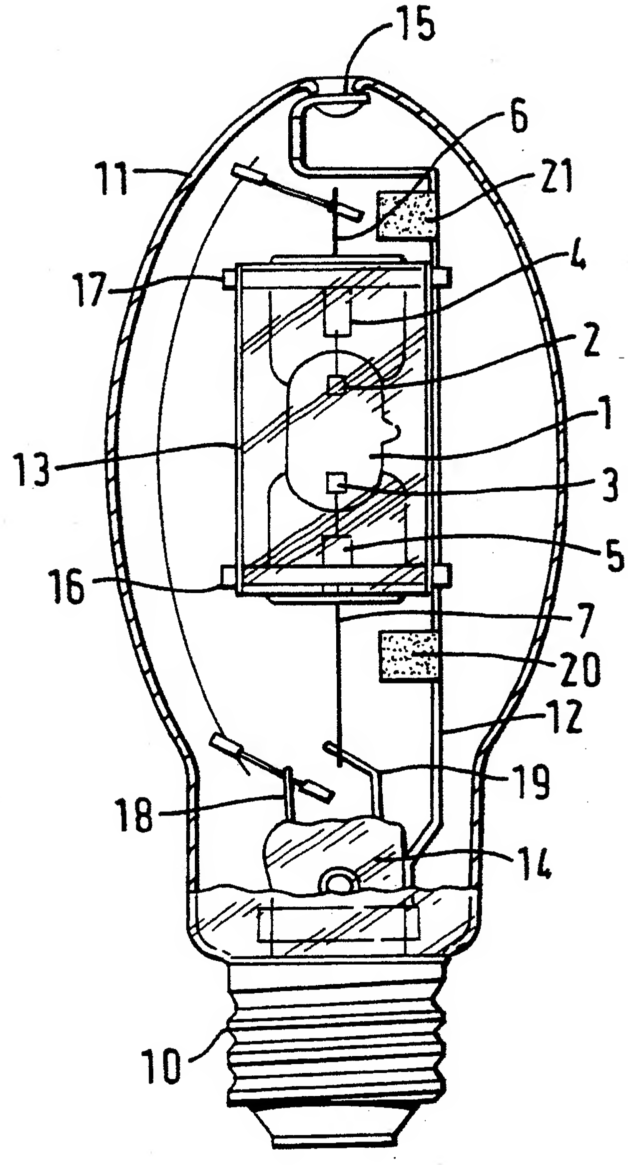


FIG. 2

CORRELATED COLOUR TEMPERATURE-ISOTEMPERATURE LINE DIAGRAM

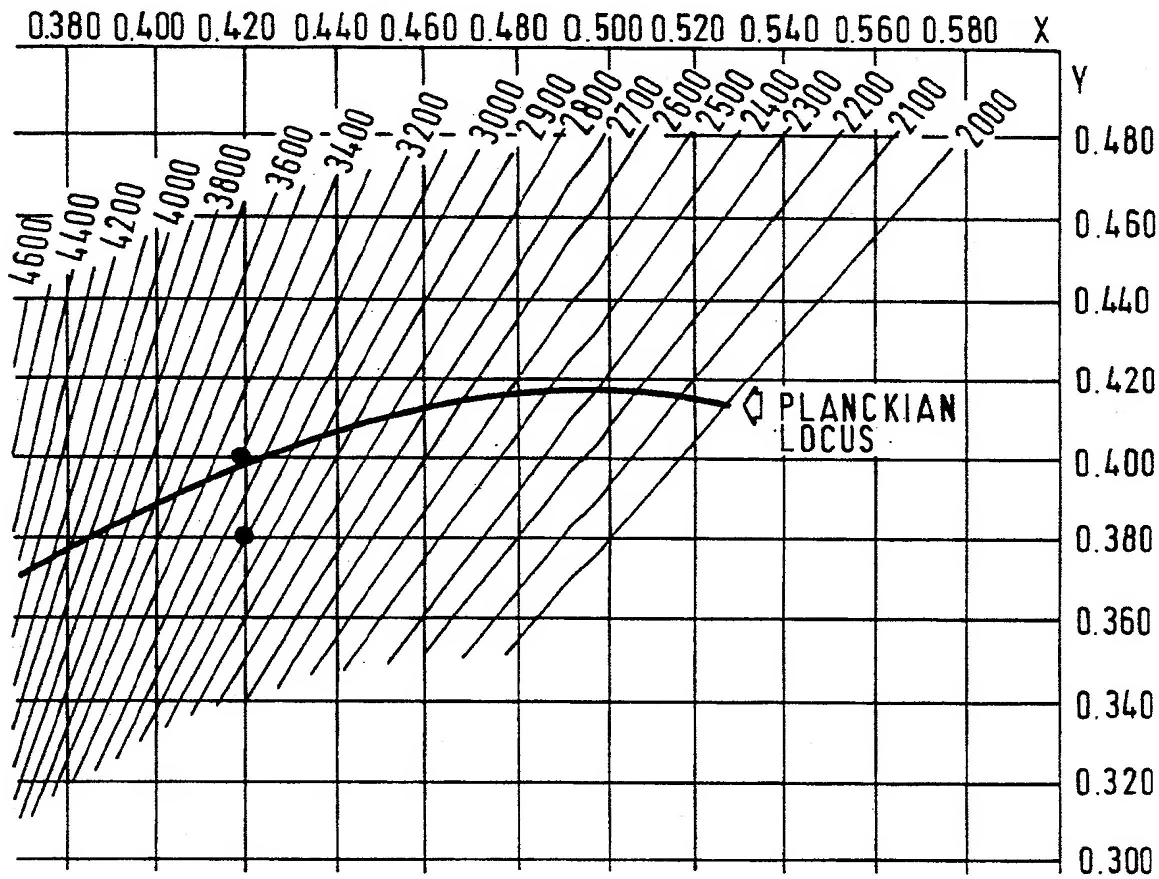
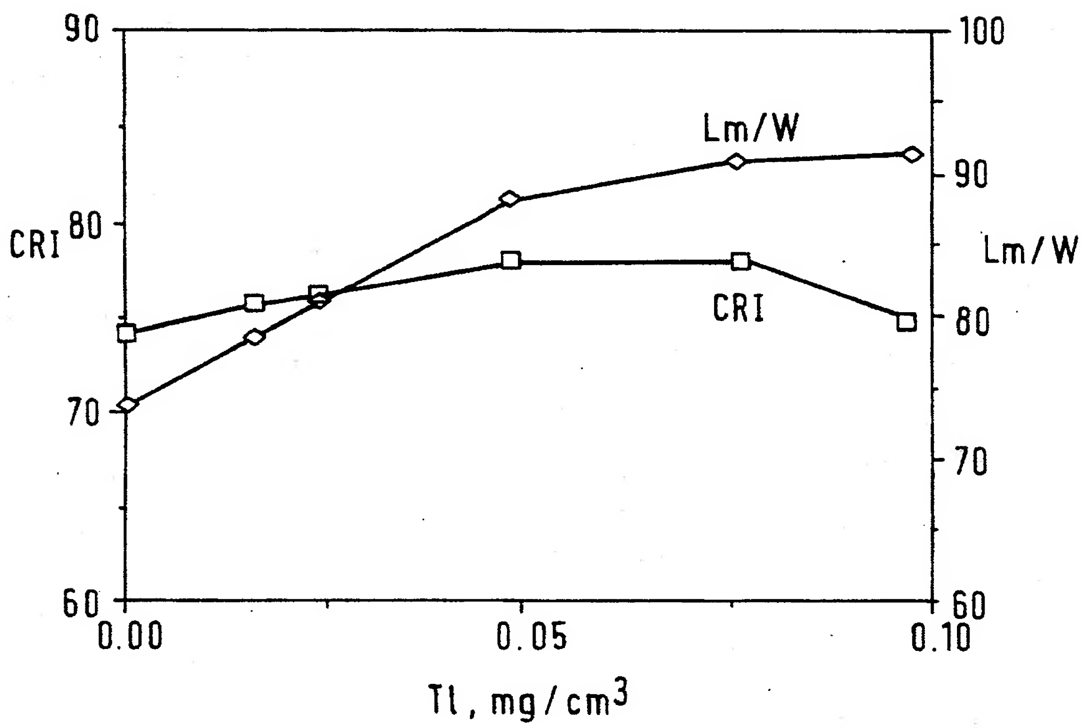


FIG. 3



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EUROPEAN SEARCH REPORT

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X A	EP-A-0 128 550 (GTE PRODUCTS CORPORATION) * abstract; claims 1,4,7 * * page 5, line 16 - line 29 * * page 7, line 14 * * page 8, line 1 - line 12 * ---	11 1,10	H01J61/12
Y,D A,D	EP-A-0 359 200 (GTE PRODUCTS CORPORATION) * abstract; claims; figure 1 * * column 5, line 1 - line 16 * * column 5, line 30 - line 42 * * column 6, line 1 - line 9 * ---	1,3,4,7 2,6,8-11	
Y	PATENT ABSTRACTS OF JAPAN vol. 10, no. 186 (E-416)28 June 1986 & JP-A-61 032 949 (HITACHI LTD) * abstract * ---	1,3,4,7,8	
Y A	DATABASE WPI Section Ch, Week 1282, 1982 Derwent Publications Ltd., London, GB; Class L, AN 82-22529E & JP-A-56 126 244 (TOKYO SHIBAURA ELEC LTD) 3 October 1981 * abstract * ---	1,3,4,7,8 11	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H01J
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26 OCTOBER 1993	MARTIN Y VICENTE M.

CATEGORY OF CITED DOCUMENTS

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
P,X	US-A-5 225 738 (RAMAIAH ET AL.) 6 July 1993	1,3,9-11	
P,Y	* abstract * * column 2, line 46 - line 68 *	4,7,8	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

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